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[The following are translations of selected articles in the Russian-language monthly journal AVIATSIYA I KOSMONAVTIKA published in Moscow. Refer to the table of contents for a listing of any articles not translated.]

Solving Uncontrolled Spin in Mi-24

92UM0108B Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 6-7

[Article by Colonel M. Yelkin, combat pilot 1st class and candidate of military sciences under the rubric "For the Arsenal of the Combat Pilot: "The Helicopter Got Into a Spin"]

[Text] *...August 1974. An airfield not far from Leninakan. Honored Test Pilot of the USSR A. Tatarchuk was performing a research flight on an Mi-24. But what happened? At the moment of making a turn a the craft banked left and pitched into a dive. All attempts to get the craft out of its difficult attitude failed. The helicopter, the blades of its main rotor (NV) brushing the ground, crashed and was destroyed. The pilot fortunately survived...*

"The helicopter entered a spin"—that conclusion could be heard more than once after such situations, even though none of the specialists could explain the physical essence of that phenomenon at the time.

The pilots encountered it for the first time in operation of the Mi-24—our first combat helicopter with increased unit payloads for the propellor area. It is distinguished from a spontaneous turn by the fact that the craft moved in the air with a large left bank and negative pitch angles sometimes reaching 50-60° with a constant or variable turn radius. Such situations are accompanied by alternating G-forces and the dangling of the crew members from their restraining belts. The impression created among fliers is that of someone, hanging onto the tail boom, powerfully spinning the helicopter.

Specialists at the OKB [Experimental Design Bureau] imeni M.L. Mil and a number of scientific institutions of the Ministry of Defense, in order to determine the essence of this phenomenon and devise practical recommendations for pilots both on how to avoid a spin and what actions to take if they get into one, conducted research that showed that the principal cause for the development of spin in a helicopter is the transition of the control rotor (RV) to a vortex ring mode (RVK).

In a case where the RV is operating at an oblique flow (Fig. 1a), the velocity vector of the oncoming flow is located outside the realm of RVK and the RV creates the necessary thrust T_{rv} to balance the helicopter, which is always in flight with a forward speed of more than 50 km/hr. However, at low speeds and with energetic movements of the helicopter to the right, the execution of left turns or [flight] in a strong crosswind from the right, the velocity vector of the oncoming flow can fall into the RVK region (Fig. 1b), which leads to a sharp drop in the RV thrust on the value of ΔT_{rv} and, as a consequence, to transverse imbalance of the helicopter. In that case it begins an energetic turn to the left with a simultaneous increase in right slippage. The airflow will now be coming onto the RV from an azimuth of 270-300°, which

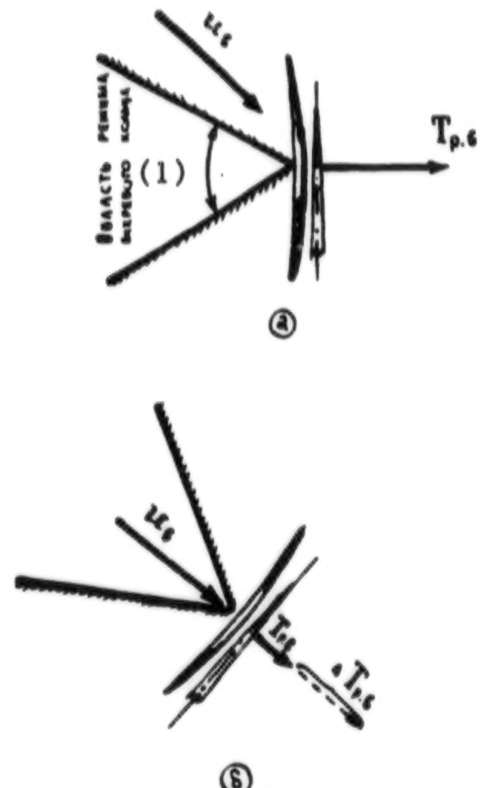

Fig. 1.

Key:
1. Area of vortex-ring mode

will cause the cone of the NV to drop forward and to the left—the helicopter turns sharply into a dive and banks.

In such a situation the pilot, pulling the control stick (RU) toward himself to the stop and to the right while simultaneously pushing the pedal entirely against the rotation, tries to bring the craft to a normal attitude. But he cannot do so. Why?

It is useful to recall here that according to the law of blade motion of the NV in transition to an oblique airflow, even an insignificant movement of the helicopter leads to an energetic (especially in a strong wind) drop of the cone of revolution of the NV, usually observed at the start of acceleration V in a helicopter-style takeoff. If the pilot does not let the stick out at V = 40-50 km/hr, the helicopter noses up sharply. The angles of attack of the NV that arise therein do not make it possible to rectify the situation by letting out the stick completely.

We will now consider an analogous situation (due to "non-indifference" of the NV to the oncoming airflow) that arises, however, in the lateral movement of the helicopter, and we will propose that the left bank has reached 20° in movement left and the RV thrust has dropped sharply. The craft, continuing to move in the same direction, drops its nose energetically and simultaneously turns relative to its vertical axis, thereby getting

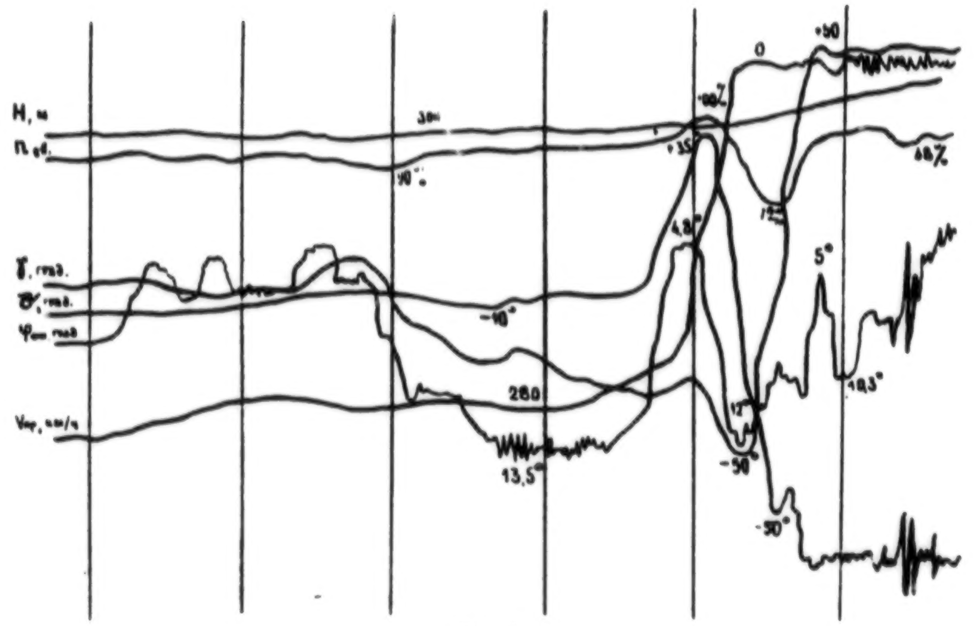

Fig. 2.

into a spin (spiral movement). It is noteworthy that a tendency to increase the angles of bank and pitch is observed in that case—the helicopter seems to be trying to get out of the spin itself. But... a paradox! The pilot, not realizing that, impedes it by pulling back the stick, with it completely back and inclined to the right to the stop, thereby forcing the craft to rotate at high speed (on the order of 180 degrees/sec). In a similar situation he should therefore, however counter-intuitive his actions may look (keeping in mind, of course, the reserves of altitude), lessen his pull on the stick and decrease the pitch of the rotor, thereby allowing the helicopter to increase its bank and pitch into a dive. Its revolution will cease after 0.5-1 rotations, and it will begin to move forward.

Pilots sometimes encounter the phenomenon of the "unintentional pitching" of the helicopter in the air, as shown by the experience of combat operations of army aviation in the Republic of Afghanistan. There were cases where the process of spontaneous increase in the pitch angle and G-forces occurred so fast that it caused the "locking" of the stick in a longitudinal attitude. Forward speed died out rapidly simultaneously with that, along with the spontaneous overspeeding of the NV and its subsequent drop below the minimally allowable levels, leading to a loss of RV thrust and the non-intentional turning of the helicopter.

In such cases the pilots, letting the pedals out to bank, switched the craft over into a dive—performing a steep climb into a dive. Many of them, however, made uncoordinated movements with the control stick therein (large slips angles arose for the helicopter), which inevitably led to getting into a spin. This situation was sometimes moreover aggravated by a sharp increase in the amplitude of the flywheel movements of the RV blades, and they, crushing the stops restricting their sweep, hit the tail boom, sometimes shearing it off along with the intermediate gearing. Here is an example.

Senior Lieutenant A. Bocharov, performing energetic maneuvering as part of a group, first permitted the "uninetntional pitching" of the helicopter, and then its entry into a spin. The pilot typically did not even pay any attention to the increased level of vibration of the craft (and that is considered to be a warning signal of its entry into critical mode) and continued to perform the maneuver. The consequences of the error proved to be tragic. Fig. 2 presents the parameters of this flight as recorded on the SARPP [automatic flight data recorder] tape.

It must be noted that a number of methodological recommendations have already been developed for flight personnel to reduce the likelihood of getting into a spin when getting out of an "unintended pitching," and helicopter designs have been refined for the purpose of preventing the RV blades from hitting the tail boom. Practice shows, however, that the problem has not been completely solved. Flight personnel should thus know that in order to avoid a spin in the situation under consideration, the overall pitch of the NV must be reduced smoothly by 1.5-2°—this will immediately restore the longitudinal controllability of the craft and reduce the level of vibrations of the craft—and a steep climb into a dive must then be performed through coordinated movements of the control levers. If it is not possible to avoid getting into a spin, the stick must be set in a neutral position and the right pedal set forward to the stop without altering the overall pitch of the NV (the strong vibrations of the craft that arise therein testify to the switch of both rotors to oblique flow). When (literally after an instant) the helicopter stops rotating with a large

negative pitch angle, it is necessary to accelerate to 70 kmph and shift smoothly into level flight. The reserve of altitude for getting out of the spin that is a consequence of a "unitended pitching" should be no less than 600 meters.

The pilots of army aviation often knowingly used legally prohibited flight modes in the course of combat operations in Afghanistan, as has already been discussed in the pages of the journal (see AVIATSIYA I KOSMONAVTIKA, 1990, Nos. 4, 7). They thus successfully used slip in the execution of spatial maneuvering: skillfully varying the values of the angle of banking, pitch and slip, the pilots cut by two thirds the time for bringing the combat craft out of a dive when attacking ground targets, achieving high effectiveness in the destruction of target air defenses.

Or another example—the use of slip when descending while coming in for a landing on a spiral, when the pilot, having established the maximum operating mode for the engine and a vertical velocity of 40-45 m/sec, maintained the following flight parameters: $V = 200$ km/hr, $\gamma = 30°$, $\nu = 30°$ and $B = 20°$. Immediately before landing the pilot, through increases in the ν to -10°, killed the speed of the helicopter to 8-10 meters/sec over 2-3 seconds, and thanks to a further increase in the overall pitch to 5-6° turned the helicopter onto a horizontal plane. This maneuver made it possible for the pilot to make a landing approach from an altitude of 1,500 meters over 40 seconds. Cases should also be noted where the maintenance of the parameters in turns was accomplished by the pilots via changes in the pitch angle.

Here is what is noteworthy, however: all such maneuvers are none other than a spin. The bank actually reached 50-60° and the negative angles of pitch 30-60° by setting the pedals forward to the stop for a turn (disrupting the equilibrium of the moments Mr_{rv} and Mr_{nv}). The combat craft, however, was controllable in these cases in view of the preservation of the oblique flow of both rotors! Let the pilot lose forward velocity to below 100 km/hr in the process of this maneuvering, and a dangerous situation arises that often occurs in modes close to hovering.

The conclusion could be drawn from the aforementioned that the pilots encountered one and the same mode in all of the situations described. But whereas at speeds of more than 100 km/hr it had a positive influence on the effectiveness of combat maneuvers, when it was lost below the indicated threshold value it led to tragic consequences.

It must regrettably be noted that the question of training flight personnel in piloting a helicopter in critical modes has not yet been resolved. How can one in that case discuss the safety of flights in a combat situation, if on training flights it is ensured principally through bans and restrictions, depriving the pilots of an opportunity to utilize fully the maneuverability of the rotary-winged craft?

One cannot agree with the authors of the article "Teaching the Spin" (AVIATSIYA I KOSMONAVTIKA, 1991, No. 1), who express an opinion of the necessity of "determining intelligent limits in mastering the spin according to the types of airframes, developing a technique for teaching it and creating a textbook with a regard for the results of the flight testing of recent years."

Today, no matter what the level at which the calls for increased aerial proficiency by fliers are heard, they will remain just calls if practical steps are not undertaken to master those maneuvers whose execution often saved the lives of our pilots in the course of combat operations. Can the experience of Afghanistan really have taught us nothing?

Economic Costs of Air Accidents Estimated

92UM0108C Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 10-12

[Article by senior engineer and researcher Lieutenant-Colonel S. Bolotin under the rubric "Flight Safety and Economics": "The Price of Accidents"]

[Text] How much, in your opinion, does flight safety cost? If you feel it is too expensive, that means you do not know how much air accidents cost. It must be noted here that these figures are still secret—if not sealed with seven seals, then with only a few less. The classified nature of our military-economic information is a consequence of the ubiquitous departmental secrecy, sometimes concealing incompetent decisions or decisions for which publicity is not desired. The lack of concrete data does not permit the comparison of expenditures and losses, *i.e.* counting up the effectiveness of measures aimed at reducing the accident rate, which under conditions of the coming market is far from a secondary matter. The military budget of the United States, by the way, contains detailed tactical-technical data on programs and types of weapons with a precise indication of their quantities, delivery deadlines and costs.

The adoption of new methods for managing the activity of aviation subunits is being markedly restrained by the scarcity of economic knowledge among the corresponding commanders and officers. One even frequently hears that an aircraft, lost as the result of an air accident, cost nothing—after all, it had been paid for some time before...

A military aircraft, like any other type of arms or military hardware, satisfies the needs of the people for defense, and thus possesses consumer value. The loss of a combat aircraft and crew means that the likelihood of the safe existence of a society is decreased—naturally, provided that the quantity of aviation equipment and personnel does not exceed the optimal level from the point of view of defensive sufficiency.

The price of a new aircraft supplied to the troops includes the spending on its production (cost) and a share of standard profits. The opinion of scholars occupied with the problem of conversion of the Soviet military-industrial complex is unequivocal that procurements of military hardware here are measured using a "rubber yardstick"—the prices do not reflect the full expenditures; there can be no talk of normal price formation without competition. USSR People's Deputy Marshal of the Soviet Union S. Akhromeyev had every reason to declare, at a session of the of the USSR Supreme Soviet Committee on Defense and State Security that was considering the military budget on 11 Nov 90, that if we do not look into price formation in the near future, it will be difficult to determine the budget overall. But is it possible to look into something in "the near future" that has not been looked into for decades?

Cost for the aviation industry, meanwhile, as for any other defense sector with priority supply of raw and other materials and equipment, is in fact of a hypothetical nature, with the profit standards regulated by the state; its formation under market conditions takes place, at the same time, as the result of competition for military orders.

It should nonetheless be understood herein that the laws of military business are somewhat different than the principles of the commercial market. The Pentagon leadership, for example, under pressure from Congress and the public, is trying to expand the sphere of activity of the laws of the market in the military sector, increasing the share of orders allocated on a competitive basis. Despite an increase in that to 50 or more percent for certain branches of the service, it is still an average of just 5-10 percent.

The necessity of fundamental changes in the practice of mutual relations between the Pentagon and its contractors was dictated by serious shortcomings that were ascertained in the system of procurement for weapons and military hardware. Cases of artificial price hikes for military output and its insufficient quality, among other things, were given wide publicity in the United States at the beginning of the 1980s, which forced the military and political leadership to undertake a series of steps in that area; the most important of those was the adoption of an automated system for the management of procurements and logistical support. Some 30-50 of every 100 dollars could be saved, in the opinion of specialists at the U.S. Department of Defense, through the automated financial monitoring of military corporations, an increase in the effectiveness of follow-up checking and conformity of the estimates submitted to the actual production expenses.

"...According to some estimates, the price index for arms and military hardware will be approximately 1.6 in 1991..." (KRASNAYA ZVEZDA of 13 Nov 90). This report suggests the idea that it would do no harm for specialists at the USSR Ministry of Defense to take a look at the experience of the American military as well.

We will try to estimate, based on the prices currently accepted here, the economic damages caused to the state by air accidents in armed forces fighter aviation. The calculations are in prices as of 2 Apr 91.

Economics includes such terms as "direct losses," "indirect losses" and "lost profits." We will limit ourselves to estimating only the direct costs for the sake of simplicity. It is easy to say "based on currently accepted prices." But after all, they remain "sealed behind seven seals!" We will take the risk of breaking one of the "seals," considering an accident of a MiG-25 fighter that occurred in September of last year at a southern airfield by way of example.

"...After takeoff and retraction of landing gear, the 'Minimum fuel reserve' light came on at 100 meters. Reporting this to the flight supervisor, the pilot began coming around to land. The right engine stopped after a few seconds, then the left. The pilot ejected safely after the stoppage of both engines. The aircraft, upon hitting the ground, was demolished and partly burned."

We will try to establish what this aircraft cost.

It is known that the budget appropriations for the procurement of arms and military hardware were 83.8 billion dollars in the United States and 31 billion rubles in the USSR in 1990, *i.e.* the ratio of these expenditures is 2.7:1. The military parity that exists between our two countries allows us to make the assumption that the types and quantities of arms procured by the U.S. Department of Defense and the USSR Ministry of Defense are analogous. Using this ratio, then, we can obtain an approximate value of the cost of our aviation equipment. If the F-16 costs 15-17 million dollars, the MiG-29 is then 5-6 million rubles, and if the B-1B costs 228 million dollars, then the Tu-160 costs 84 million rubles, and so on.

But let us return to the MiG-25 that was destroyed as a result of the accident. This type of fighter is not the most modern in domestic aviation, and its cost is thus naturally less than 5-6 million rubles—possibly 2 million. The plane that was lost had used up 70 percent of its service life, meaning that its present value had decreased by the amount of the amortized cost (the cost of the depreciation) and was 600,000 rubles at the time of the accident. Adding to that value plant repairs to extend service life (we will assume that it was 10 percent of the initial cost of the aircraft), we obtain an approximate value of the economic damages from the loss of the aircraft of 800,000 rubles.

We will turn again to the U.S. military budget to estimate the damages from the loss of the air-to-air missile that was on the fighter. The Sparrow missiles were procured by the U.S. Department of Defense in 1985 at 70,000 dollars "each." The "dollar/ruble" ratio for that year is unfortunately unknown, so we will use the former one of 2.7:1. Proceeding from that, a domestic missile analogous to the American one cost 26,000 rubles in 1985, and in the range of 60,000 rubles in 1990 allowing

for annual inflation of 18 percent (IZVESTIYA of 28 Oct 90).[1] If there were four such missiles, their loss cost the state 240,000 rubles.

"...Deputy Squadron Commander Combat Pilot 1st Class Major A. Rassakhatskiy had mastered seven types of aircraft and had flown more than 1,000 hours. He acted competently, coolly and confidently in this situation..."

Major Rassakhatskiy survived. But do air accidents always end so favorably? Our task is to assess the damages caused to the state in the event of the loss of a pilot as a specialist on whose training a certain sum was expended. Events that result in the removal of the pilot from flight operations or his discharge from the service entirely also require the corresponding assessment in this sense.

Expenditures for the training of a military pilot in the United States are about 500,000 dollars, in Great Britain 2.5 million pounds sterling and, in the USSR, several times more than the cost of training at a general service school (and that is about 10,000 rubles a year). We would thus not be in error if we say that the training of our military pilot costs the state no less than 100,000 rubles. That total includes expenses for the maintenance of the personnel of the service schools and aviation training regiments, the maintenance and reinforcement of the physical plant, the cost of fuels and aviation equipment and the like.

The "value" of the pilot, like any specialist, grows with increased levels of professionalism. The training of a 1st-class pilot is valued at a few million rubles. A few is, probably, no less than two? The dismissal of a single highly trained pilot from U.S. fighter aviation, by way of example, costs the American taxpayer 13 million dollars (VESTNIK PVO, 1989, No. 11).

But it is well known that more than pilots and servicemen perish in a crash. An assessment where the amount of the damages includes only the insurance payments to relatives of a deceased passenger (1,000 rubles until recently), as is done in the Ministry of Civil Aviation, cannot be suitable from the viewpoint of the state. Calculations of the lost profits from the failure to make use of the people who are deceased, or those who have lost their ability to work who have mastered these or those professions, is also required in an air crash.

And what is the damage inflicted by air crashes to nature, buildings, structures and, finally, bystanders? It could be commensurate or even exceed the damages from the loss of the aircraft and the death of the pilot. Many recall how a MiG-23 fighter "landed" in Belgium, or the recent case where an Su-17 fighter-bomber tore into a residential building in Amur Oblast.

Finally, the cost of investigating an air accident, the aim of which is to ascertain all of the hazardous factors and devise preventive measures that would rule out such incidents in the future, should also be added to the economic costs of the accident. Time and money are required for this.

The direct economic cost to the state as the result of the aforementioned MiG-25 fighter accident thus totals 1,050,000 million rubles (the cost of the aircraft allowing for depreciations—600,000, repairs to the aircraft—200,000, the four missiles—240,000, and the investigation—10,000). We will call these the hypothetical "minimum" losses, *i.e.* the damages from the loss of an "old" aircraft, without the death of the pilot, with a minimal impact on the environment.

Even a simple enumeration of the losses connected with an air accident suggests the idea that a professional economist, the more so from an independent commission, should be at the scene of the investigation. Otherwise, with our public (read that no one's) ownership, it is always possible to agree with the local authorities "not to notice" a burned-up electrical-transmission line, a destroyed house or a torn-up kolkhoz field.

We will now try to assess the losses from accidents and crashes on the scale of all the aviation of the USSR armed forces. It is no secret that our pilots have considerably less flying time than pilots in the United States. The yearly total flying time for pilots in fighter aviation in the NATO armies is no less than 180 hours. Say it is half that, *i.e.* 90 hours, for Soviet pilots.

It is well known that the average flying time per air accident is 8,000 hours for the MiG-23 aircraft and 10,000 for the Su-17 (AVIATSIYA I KOSMONAVTIKA, 1990, No. 6). There were 8,207 combat aircraft in fighter and bomber aviation in our armed forces as of 1 Jan 90. Assuming that the number of pilots we have is roughly equal to the number of aircraft, and the flying time per accident for the "average" fighter is 10,000 hours, we determine an approximate value of the number of air accidents as:

$$N_{aa} = (8,200 \times 90)/10,000 = 74.$$

Multiplying the figure obtained by the "minimum" value of the damages, we obtain a value for the "minimum" losses over the year of about 80 million rubles. If one figures that the ratio of accidents and crashes in our aviation is equal to 1:1, we can assess the "average" losses from air crashes allowing for the loss of "old" aircraft and the death of a pilot 1st class but without any harm to the environment as about 150 million rubles a year.

It would not be too bold to assert that "expensive" aircraft are also not protected against "falls." Accidents by a MiG-29 in 1989 and an Su-27 in 1990 are proof of that. If we assume that the "contribution" of supersonic fighters is about 20 percent of the overall losses, the amount of the economic damages in that case increases to 180 million rubles. Let us call that the "maximum," even though at least three components are not being

taken into account therein—the deaths of bystanders, the destruction of ground facilities and damage to the environment.

We begin counting money here, in the complete absence of an economic approach to ensuring flight safety, only when it is necessary to "expedite" some very important document or resolution. Our state system of statistical accounting, transformed for the sake of achieving an illusion of well-being in service of the power structures, obviously leads in this case to such results, which can be believed but should not be trusted.

Safety matters here, to put it mildly, are not too well off, and not in military aviation alone. Some 20,000 people a year are deemed labor invalids each year in the USSR, and roughly the same number are killed. About 10,000 people die in fires. Chernobyl, the ship Admiral Nakhimov, the submarine Komsomolets, Arzamas, Ufa, Spitak... Searches for the origins of this safety situation in production (and not only in production) will bring us to the point where a person in our country has become a cog in the state machine, and its political and economic lawlessness is one of the principles of existence of a totalitarian regime.

The chief cause of today's misfortunes in this realm is the lack of a profoundly and comprehensively thought-out state policy that should be based first and foremost on an economic mechanism. In the United States, for example, an accident that entails the death of a worker could cost a firm 1.5 million dollars. In the USSR, even with the receipt of the miserly compensation for the maiming or death of a close relative, you have to go to a thousand and one offices. The shortsightedness of such a policy is obvious—we scrimp a ruble today, and we could lose a hundred tomorrow. The famous saying about the miser does not pertain to our state—it is not penny wise and pound foolish, it is a hundred pounds foolish.

Economic investments in flight safety include direct and indirect spending. The direct spending could hypothetically include spending for the maintenance of the service itself and the scientific-research organizations occupied with these problems, support for the functioning of automated information systems (if such exist), for preventive measures and the like. The indirect spending is the investment of monetary resources in the solution of socio-economic problems, and improving the living conditions and activity of our fliers. It has been proved that the level of flight safety is higher in those countries where national income per capita in higher, and the concern for the person is greater.

Meanwhile, how much is the spending for ensuring flight safety? Its true scope can be judged by the amount that the "accident-free" pilot receives at the end of the year from the incentive fund—20-30 rubles. An analysis of the ratio of the losses from air accidents and the spending on flight safety leads to the conclusion that the current level of the accident rate depends not on God, but on the people managing the distribution of the state budget. Even larger capital investments in flight safety will not have an immediate impact, but they will create an economic foundation for saving human lives and equipment in the future.

Footnote

1. A regard for inflation is an essential condition of such economic computations, and if it is not stipulated what prices are being used, constant or current, the calculations will be devoid of any sense.

Effect of Aircraft Ergonomics on Flight, Maintenance Errors Analyzed

92UM0108D Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 13-15

[Article by Colonel L. Ivchenko under the rubric "Military Reform: Discussing the Problem": "Once More on the 'Low Men on the Totem Pole' in Aviation"]

[Text] *I have been following the debate that has unfolded in the pages of the journal surrounding the article by A. Akimenkov, "What Keeps Our Aircraft From Being Better" (AVIATSIYA I KOSMONAVTIKA, 1990, No. 7). Judging by the reactions on the part of representatives of the Ministry of the Aviation Industry, the former test pilot evidently hit the nail on the head. And I am surprised in general by the peremptoriness with which the servants of the military-industrial (and namely the military-industrial!) complex defend the honor of the uniform without paying any attention to what is troubling the military fliers. It is for precisely that reason that I cannot stand on the sidelines. I will discuss the problems of ergonomics—the science studying the interaction of man and machine in the "man—machine—environment" system.*

In the Sky

The aircraft being sent to equip the air units should conform to the progressive achievements of science and technology in their operational and tactical performance characteristics. Technical progress, as paradoxical as it may be, leads to a considerable complication of aviation equipment, which has a negative effect on the level of its reliability, flight safety, the required number of service personnel, the operating cost and the time periods for bringing it to combat readiness. The number of failures due to erroneous actions committed by aviation technical personnel thus clearly decreases very slowly, continuing to give rise to air accidents and the precursors to them.

In most cases it is operational personnel—that is, the fliers—who are declared to be to blame for air accidents. That being so, waves of repressions roll over them regularly. Is this a fair situation?

In order to answer that question, let us become acquainted with the most typical blunders by the aviation technical personnel. They include the incorrect reading of information or hookup of control connections in the cockpit, the acceptance of "false" information as trustworthy, the mix-up of connector assemblies located close together (and identical in design) or their incorrect connection, the incorrect closure of locks for the drag chutes, the cockpit canopy or refueling nozzles, unintentional damage to equipment and elements of the on-board circuitry, the over- or under-tightening of connections and the incorrect setting of assemblies.

Sheer sloppiness and inattention by the specialists, at first glance. These epithets, by the way, are used regularly in the orders of officers to punish the "offenders." Guilty people who are not to blame, the so-called little guys, arise that way in aviation. Or else existing problems of ergonomics are not taken sufficiently into account when investigating accidents.

Many design and production shortcomings in older-generation aviation equipment are meanwhile transferred wholly or partially to new aircraft, preserving a negative "continuity." It is consequently an opportune time to talk about the fact that the erroneous actions cited above are provoked not only, or rather not so much, by a lack of conscientiousness by the fliers as it is by shortcomings in the equipment. That is why repressions directed against the servicing and maintenance specialists have not had, are not having and will not have the results that the commanders and senior officers are possibly counting on. According to materials in the foreign press, by the way, only about 25 percent of the failures of aircraft equipment occurs as a consequence of errors by the personnel working with it. Therefore no matter how much we experiment with the aviation engineering service [IAS] or invent new structures for it, no substantial use should be expected from it. Many of the problems of the IAS come up against the necessity of design-technology improvements to the aircraft themselves.

It has been established, through researching the ergonomic properties of aircraft-equipment design that determine the level of error-free actions by technical flight personnel in the process of servicing and maintenance, that mistakes are caused by two principal factors. First is the low degree of ergonomic conformity of the aircraft design to the psycho-physiological capabilities of the person. Erroneous actions by specialists when servicing and maintaining the aircraft, that is, are objectively provoked by design and production imperfections of the on-board systems and equipment. Second, by the shortcomings of the specific specialists (pilot, equipment). Individual specific features, primarily negative, in other words, that keep him from performing the work successfully.

The extent of conformity of the ergonomic properties of aircraft and helicopters to the psycho-physical structure of the activity of the person when operating aircraft has unfortunately not yet been fully taken into account in their design engineering and series production. Everything has been founded chiefly on the personal experience of the specialists according to the "common sense" principle, without any serious scientific substantiation. This has in turn led to the fact that aircraft equipment with serious ergonomic deficiencies (properties) proves to have a negative effect on the quality of its servicing and maintenance.

Ergonomic shortcomings of aviation equipment include: inconvenient positioning, as well as multi-function purposes, of instruments, control elements and light signals (or lack thereof) in the cockpit. This leads to the incorrect readings of information and the erroneous switching of system control elements of the aircraft in flight; the identical nature of the designs of closely positioned elements and assemblies of various functional systems, whence the unintentional disruption (mix-up of the connector assemblies) of the process for performing installation, removal, adjustment and check-out operations; a failure to observe the principle of "uniqueness" of operation or assembly of mechanisms, that is, the kinematics of the mechanisms is executed in design terms in such a way that they can occupy the working position or a "false" one, or else the possibility exists of the assembly of a unit or block in a manner different from the way envisaged by the requirements of the technology; poor servicing and maintenance feasibility (convenience, accessibility) and monitorability of the design of aircraft systems; the lack of calibrated tooling and standard requirements for the tightening of various types of connectors; and, imperfections in the technical servicing and maintenance documentation, which does not reflect the specific nature of the design features and configurations of on-board equipment, which also fosters erroneous actions by the specialists.

The largest amount of errors (more than 50 percent) for the first reason are committed principally by flight and, to a lesser extent, by technical personnel. This is explained by the complexity of the tasks being performed by the crews under extreme conditions.

Many years of practice moreover testify that the most typical ergonomic flaw in an aircraft that causes erroneous actions by the flight personnel leading to the precursors to flight accidents is the insufficient transverse controllability of individual fighters (especially at large angles of attack) that is inherent in the design engineering. This worsens the countering of rotation in banking. The combined control of the rudder and the brakes on one control element (the pedals) leads to unintentional braking of one of the wheels when the pilot steps on the pedals, the destruction of the tires and the rolling of aircraft (especially ground-attack aircraft) off the runway, especially when landing in a crosswind.

Several precursors to air accidents thus occurred due to the unintentional pressing of the brake pedal by the pilot when landing in a crosswind in one ground-attack air unit of the WGF [Western Group of Forces] alone over

1988-89. The cause was the restricted nature of movements in the cockpit and the excessive sensitivity of the brakes. The likelihood of errors by the pilot increases with the full deflection of the pedals and the aircraft control stick to bank, that is, when he is countering the disruptive effects of a crosswind in bank and heading. Or here is another example.

The "fire" signal light came on in the cockpit of the aircraft (a close-support bomber) during the daytime in good weather conditions. Since it was located in the panel of emergency signals for the left engine, the pilot naturally shut down the left engine, even though the signal had actually been triggered for "fire" in the right engine. Thankfully it was a false alarm...

It has been proved that the existing numbering and choice of gradations for the altimeter scale facilitate significant errors by the pilot when reading the flight altitude value (up to 1,000 meters), especially when performing advanced and expert-level aerobatic maneuvers in bad weather conditions, which leads to air accidents or precursors to them.

The imperfect nature of signals to the pilot of a failure in the aircraft's spatial-orientation determination system (IKV) causes an incorrect determination of the position of the aircraft in space, which (especially under conditions of heavy cloud cover and turbulence) can lead to grave consequences.

...And on the Ground

Ergonomics "throws" quite a few problems at the ground specialists as well. The outwardly identical nature of the design of assemblies, units and various systems, geometric dimensions and their close positioning, first and foremost, are typical ergonomic deficiencies of aircraft causing erroneous actions by the specialists of the aviation engineering service, leading to the mix-up of plugs when hooking them up, the incorrect installation of units and assemblies performing the role of sensors or control elements in the aircraft control or navigational systems. Blunders associated with the mix-up or incorrect hookup of service lines for the fuel, hydraulics or air systems, pitot tubes or wiring plugs are especially dangerous.

The closely positioned lines for the main and booster hydraulic systems, completely identical in outward appearance and geometric dimensions, were mixed up in an interceptor unit. Liquid leaked from one system into the other in flight, which led to a change in the operating mode of the hydraulic pump and the fatigue rupture of the line. A precursor to an air accident as a result.

In another unit, this time WGF army aviation, spontaneous surging of a helicopter in the transverse control channel began during flight. The amplitude of the fluctuations was moreover increasing. Specialists in a flying laboratory of the association investigating this incident detected that the sensor for angular velocities of banking had been mounted incorrectly by the mechanic when installing the autopilot units. The deficient plant technology that permitted the mounting of the sensor in a non-operating position had let them down. There was moreover no clear marking of the direction for its installation. Add to all this a lack of experience for the mechanic performing the work.

The largest quantity—about 40 percent—of the erroneous actions by IAS specialists is committed for this group of reasons.

Design flaws of individual assemblies and mechanisms, consisting of a failure by the designer to observe the principle of "uniqueness" of operation or assembly of their parts that could be put into a false position during the servicing process, also cause erroneous actions by specialists. The fuel caps of tanks, locks for brake chutes and cockpit canopies are incorrectly closed due to this.

Violations of ergonomic requirements for ensuring the convenience and accessibility of the servicing and maintenance of aircraft equipment in its design engineering condition poor feasibility and monitorability. Some 22 percent of the errors connected with unintentional damage to the equipment, elements of the on-board circuitry and lines or the over- or under-tightening of connectors in installation occur for this reason, leading to a loss of the airtightness of systems and fire on the aircraft. Objective monitoring of the correctness of installation is lacking as well, which provides for another 16 percent increase in errors.

Experimental research has established that a certain category of flight and technical personnel requires not only more time for devising a stable (and error-free) stereotype of activity, but also loses it more quickly under the effects of unfavorable factors. These include noise, vibrations, high-frequency emissions, vapors from fuels and lubricants, meteorological effects, insufficient mechanization of physical operations, disruptions of the work and rest regimen, housing conditions and the like.

The data obtained testify to the fact that the operability and probability of errors being committed by specialists varies substantially, both over the course of the day and over the course of the work shift.

Tell me who among the commanders and senior officers organizing combat training takes this feature into account today? I would be so bold as to say—no one! The principle of "take more and throw further" reigns supreme here. The person is identified with an inanimate mechanism... It has been established, when analyzing the blunders of aviation technical personnel, that there is no unequivocal link between the essence of an error and the reasons causing it. One and the same mistake could have varying causes among various performers depending on qualifications, experience, individual psycho-physiological qualities, degree of organization of the work etc.

One can state convincingly, when considering the ergonomic perfection of the design of an aircraft from the

point of view of its error-free operation and flight safety (depending on the level of reliability of the aviation equipment), that an insufficient level of it is determined first and foremost by a limited quantity of research in this realm and, as a consequence, a lack of comprehensive standard requirements for the equipment being designed.

Foreign and domestic experience shows that the adoption into aircraft design-engineering, manufacture and operating practice of ergonomic developments aimed at the error-free actions of flight and technical personnel can not only rise combat readiness and the safety of flights, but can also have a certain economic impact. We should say something about that here, however.

The specific nature of the economic impact of ergonomic developments consists of the fact that spending is increased somewhat for the manufacturer of the aircraft, and the spending in the field units is reduced substantially. The state wins out nonetheless. But what are the economic interests of the state to the military-industrial complex compared to its own?! Nothing at all! An abstraction! Charity begins at home, as they say.

That is why economic methods of influencing MAP [Ministry of the Aviation Industry] and a system of material incentives must be considered for a vested interest for industry in the fulfillment of ergonomic developments.

How is this problem solved in the leading aviation powers? Analyzing the level of design perfection of foreign aircraft (tactical aviation) and the methods of achieving it, it should be noted that the problem of the ergonomic nature of aviation equipment in the United States, for example, arose at the beginning of the 1960s. There are five reasons for this: the increased complexity and cost of the newly created aviation equipment; the large labor expenditures required for performing technical maintenance (labor expenditures per hour of flying time tripled and reached 40-65 man-hours); the reduction in the level of combat readiness and effectiveness of the use of aviation equipment; the increased cost of its operation and repairs; and, the low effectiveness of measures aimed at solving these problems through a rise in reliability characteristics.

Even the first attempts of aviation firms to raise the ergonomic nature of aircraft via improvements in the adaptability of the design to technical servicing and maintenance have demonstrated the large opportunities in this area. The labor-intensiveness of technical maintenance was reduced from 40 to 19 man-hours per hour of flying time as the result of modifications and refinements performed on the F-100A aircraft. Analogous measures performed for the F-111A fighter-bomber made it possible to reduce the labor-intensiveness of maintenance by 20 percent, while also reducing the costs of the maintenance.

Similar work to improve the ergonomics of aircraft equipment that is in operation, however, requires considerable expenditures of time, labor and funds. The United States, England and France have thus created a system that provides for the formation of requirements for ergonomics (evaluating and forecasting ergonomic indicators) at the stage of aircraft design engineering.

It is known from materials in the foreign press that whereas the aircraft of tactical aviation in the United States had labor expenditures of 35-45 man-hours per hour of flying time in the period from 1954 through 1966, a substantial reduction in that value to nine man-hours occurred in 1970-80. Not even the continuing, significant increase in the complexity of the designs of systems and equipment, to which our own industrial complex doggedly refers, was a hindrance to this.

We thus see from an analysis of the statistical materials and operating experience of aviation equipment that the problem of the ergonomics of aircraft, materializing in a large percentage of air accidents and the precursors to them and absolutely unjustly blamed on the flight and technical personnel, is far from solved today. Many GOSTs [State All-Union Standards] exist today that contain requirements for the development and manufacture of aviation equipment in which, unfortunately, only general ergonomic requirements are set forth for design execution.

The engineers of our associations, apropos of the "pilot (IAS specialist)—aviation equipment—environment" system, have developed a standard technique for determining the possible types of errors and their properties, along with methods of recording them. It also takes into account their connection with the ergonomic shortcomings of the aircraft equipment and records conditions and circumstances that could be utilized to clarify the cause-and-effect links that lead to blunders.

A list of design shortcomings (with a regard for the extent of their danger) leading to erroneous actions by technical and flight personnel servicing specific types of aircraft is being compiled on the basis of a summary of that material. This list is being sent to industry to eliminate the shortcomings in aviation equipment in the field and modernize that being manufactured.

A detailed analysis of erroneous actions makes it possible to evaluate the effects of the skills, age and seniority of the flier on the error-free servicing of the aviation equipment. Measures have been worked out to avoid erroneous actions by technical service personnel in units, including a study of the causes of errors, improvements in the training base, the performance of specific simulations and the implementation of the essential monitoring.

A knowledge of, and regard for, the ergonomic shortcomings of aviation equipment and the nature of their effects on the causes of erroneous actions by personnel will make it possible for us to incorporate effective measures

in the air regiments to neutralize errors by fliers and reduce by 15 percent the quantity of precursors to flight accidents that are the fault of the IAS specialists.

That is why it can be said without exaggeration that one of the principal tasks of engineers in all fields is the development of methods to gather and analyze statistical data on the erroneous actions of flight and servicing personnel, determine its connection with ergonomic shortcomings in the aviation equipment and devise substantiated practical recommendations both on how to avoid errors and all sorts of blunders by flight and service personnel and to improve the ergonomics of the aviation equipment in industry. It is a delusion to hope that MAP will display some concern for us servicing and maintenance personnel. It has no vested interest in it. That means we must take steps ourselves.

Aerial Refueling Expands Capabilities of Su-24M Aircraft

92UM0108E Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 16-19

[Article by Colonel N. Neshkumay under the rubric "The Time Has Come to Tell...": "Increasing Flight Range"]

[Text] *AVIATSIYA I KOSMONAVTIKA (1991, No. 5) has already acquainted the readers with the history of the creation and assimilation of the Su-24 close-support bomber. Judging from the mail to the editors, many are also interested in the aerial refueling process for those aircraft. Military Pilot-Expert Marksman Colonel N. Neshkumay tells about it.*

Nothing was known of the aerial refueling of the Su-24 up until quite recently—the aircraft itself was only known to a narrow circle of specialists. And it is entirely natural that many fliers, having picked up information on the latest super-long-range flights of aircraft from U.S. tactical aviation that were accomplished with several aerial refuelings (it is enough to recall the raid by F-111 bombers based in Great Britain on the Libyan cities of Tripoli and Benghazi, unprecedented in nature), are asking the question, what about the Soviet Air Forces?

It is no secret that aerial refueling is a stage completed long ago for the crews of our long-range aviation. The crews of the close-support bombers also set about assimilating this operation when the Su-24M equipped with refueling apparatus—a fuel intake hose that retracts into the nose portion of the fuselage along with a pumping system—began arriving in service in the middle of the 1980s. It is noteworthy that this aircraft may be employed as a refueling aircraft as well, when it is fitted with an standard external refueling assembly (UPAZ) intended for pumping fuel according to the "hose—sleeve—probe" configuration.

A more significant expansion of the combat capabilities of the Su-24M is achieved, however, with the use of an Il-78 aircraft as a tanker; one refueling from it increases the tactical range of a close-support bomber by 85-90 percent, and two—outbound and returning—by 135-180 percent.

It must be added to this that refueling of the Su-24M is supported at night as well as in the daytime, and either for single crews or as part of a pair. Lights have been installed on the bombers for this purpose, with the aid of which the crews accomplish the visual detection of the tanker and, after convergence with it, the illumination of the lower surfaces of its wings and the hose with the sleeve.

Now the refueling operation itself. Its accomplishment, as experience has shown, requires the detailed and careful training of the flight personnel. A refueling flight has for this purpose been hypothetically divided into stages that can be considered individual elements of flight training: getting to the refueling zone; meeting and convergence of the aircraft with the tankers to the range of visual detection; formation flying and the execution of contact; and, aerial refueling.

The sections of the flight routes of the strike aircraft to the target (outbound refueling) and during the return from the assignment (return refueling) are planned in advanced for the execution of this complex maneuver. The choice of these areas is made from the calculation that at the line where the fuel receipt is completed, the close-support bombers should have enough of a reserve of fuel to provide for the execution of the combat mission, return to the airfield or the reaching of a location for a new meeting with the tankers to perform return refueling. A zone of 100-120 kilometers long is required in practice to transfer 8,000-9,000 kilograms of fuel from Il-78 refueling aircraft to each of 10-12 aircraft that are part of a strike-group formation.

The crews of the close-support bombers, having reached the encounter line with the tanker group, switch to visual search and, after detection, begin the process of taking up formation with them. Taking their places by pairs in the overall formation and having decided to make contact, the pilots of the aircraft being refueled report same to the crew of the tanker by radio and begin to converge in sequence—first the lead and then the wingman, visually keeping the hose, sleeve and probe hose on a line.

At this stage the pilot first makes a rough alignment—he directs the probe into the area of the sleeve by maneuvering the aircraft. When the distance between them is reduced to a minimum, the pilot makes the speed of convergence more precise (an incomplete lock-on of the locks on the head of the sleeve with the probe hose is possible if it is less than 1.5-2 meters/second, which leads to the spilling of fuel), makes a final decision to execute contact and carries out a precise alignment. He is forced to maintain his place in the formation without error

during the flow of the fuel, not diverting his attention from the tanker. The navigator monitors the receipt of the fuel.

Upon the completion of refueling the Su-24Ms move away from the tanker one by one, reforming into the assigned battle formation and taking the planned heading, while the refueling aircraft break off to the waiting area or in the direction of their home airfield at their own altitudes.

Aerial refueling is one of the most complicated elements of flight training, requiring of the pilots a high level of piloting technique and the development of solid skills in the estimation by eye of the ranges between aircraft in the air.

The execution of such flights is accompanied by a considerable increase in the nervous-emotional stresses on the crew commander, who bears full responsibility for the correctness, precision and timeliness of the performance of all elements of the assignment. It is enough to cite as an example the fact that the pulse rate of some pilots reaches 150-160 beats/minute in the most crucial stages—the contact and flow of fuel.

The monotonous nature of their activity in prolonged (more than four hours) flight also proves to have a negative effect on the psycho-physiological state of the crew members of the Su-24Ms, which brings about the acute necessity of seeking out effective methods of raising the ability of the pilot and navigator to perform. One such method is their performance of physical exercises of a static-dynamic nature right at their workstations in their ejection seats. The use of anti-G suits is also envisaged for the same purpose.

It must be noted in conclusion that the aerial refueling of Su-24M aircraft makes them an all-purpose means of acting against enemy targets in various combat situations.

New Ideas Advanced at Moscow VDNKh Space Exhibition

92UM0108F Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 30-31

[Article by Lieutenant-Colonel V. Maksimovskiy under the rubric "Space Science for the National Economy": "Space That Can Be Touched"]

[Text] The international exhibition "To the Stars—91" devoted to the flight of Yu. Gagarin that was held in April at the USSR VDNKh [Exhibition of the Achievements of the National Economy] summed up, as it were, the 30-year path of Soviet space science.

The exhibition won the right to exist thanks to the efforts of the USSR Union of Philatelists, and it was conceived as a philatelic one. The Moskva Center for the Adoption of the Achievements of Science and Technology that held it, however, decided to expand the theme of the exposition. The organization and holding of intersector and specialized domestic and foreign exhibitions, fairs, auctions and symposia was one of the important areas of its activity.

The exposition, as is customary, began with a historical section that—thanks to the non-traditional placement of the displays—looked very attractive. It was the first time, for example, that almost all of the visitors had seen the layout of S. Korolev's office.

The organizers, however, while giving the truly heroic past its due, placed the principal focus on demonstrating the possibilities of modern technology. Many leading space firms expressed a desire to take part in the exhibition. But not all. Why? Perhaps a simple mercantile approach had been triggered—what's in it for us? I heard those words, for example, at the KB [design bureau] where the first space braking engine installation to provide for the return of Yu. Gagarin to earth had been created in an inconceivably short time. I am sure than the KB's founder, A. Isayev, would have taken advantage of the opportunity to show the achievements of his collective.

Perhaps some organizations, seeing no direct gain, brushed aside the prestige of the country, which it is especially important to maintain in difficult times. And the visitors who came to the pavilion? There were quite a few of them, by the way. Could they really not have had the right to see what had been done with their money?...

It was mock-ups that were presented at the exhibition, by and large. The visitors, however, encountered a "full-grown" Almaz heavy spacecraft. We heard that name very often, even though the satellite was created several years ago and was working in orbit for the first time in 1987-89 under the pseudonym of Kosmos-1870. The Machine Building NPO [Scientific-Production Association] is offering the use of its greater capabilities in the interests of the national economy as well.

And now here are examples of the appearance of multiple variations for the resolution of various types of tasks. We already have an idea of the already-created Energiya-Buran reusable air/space system. It was naturally presented at the exhibition. The Molniya NPO, however, has proposed its own design for an orbital aircraft. It has the capability of being launched from the An-255 Mriya and can support basic freight traffic, replacing medium-class launch vehicles. It should be more efficient than those and the superheavy Energiya launch system in putting satellites of up to 7-8 tons into orbit.

Another example. The Energiya NPO, wishing to make use of the unique capabilities of its launch vehicle, is proposing to overcome decisively our shameful backwardness in the realm of communications and television with the aid of an integrated satellite information system

based on heavy space platforms. Only three such facilities need to be placed into stationary orbits in order to provide for the country's needs today. Remarkable? Yes! And the main thing is that it is realistic in practice. Is it worth not leaving well enough alone? It is.

And now an enterprise that arose seemingly out of nothing is proposing an alternative, once again based on existing technology. Knowledgeable people were thunderstruck by its participation in the exhibition. The Machine-Building KB from the Urals city of Miass really was a debutante accessible to the people at the exhibition. So then, the idea of the specialists from the KB consists of using rockets that are already developed and are highly reliable as light launch vehicles. This launch method could put satellites of a few hundred kilograms into medium and low orbits. Not much? This direction is being actively pursued in the United States, and not just for the accomplishment of civilian tasks. Small satellites could be created for various purposes, and especially for communications, even with our level of electronics. Dozens of them in low orbits are able to perform functions similar to those for which the heavy communications platforms are intended.

One cannot develop a rocket or spacecraft, like a medicine, for all cases in life. It is necessary to determine the goal and attain it with a rational set of technical equipment that is effective in its realm...

A mock-up of the Luna-1992 international tourist and scientific and technical center, among other exhibits, was in the Glavkosmos [Main Space Administration] section. The profound idea and refined incarnation attracted the attention of the visitors. The Soviet-Finnish Kosmos-Luna joint venture intends to build its principal structures as early as 1992 on the picturesque territory allotted for it not far from the city of Tampere in Finland.

And what about us—the motherland of practical space science? We have no funds, they say. But the Finns are realizing this project, and not at a loss to themselves! And they are concerned with the education, upbringing and relaxation of their citizens at the same time. Can we but envy the former outer reaches of the Russian empire?

But we will never get out of the situation we have gotten into that way. New approaches and young people able to think dialectically and systematically are needed. We have them, but we must see that there are more and that we do not hinder their work. It is thus very important that one of the sections in the "grown-up" exhibition was represented by the Krasnoyarsk School of Space Science. This is a completely new and effective form of training the succeeding generations for space. There should be many such schools. This is not a matter for enthusiasts and sponsors from Krasnoyarsk alone. This is a nationwide task. The country is meanwhile economizing in education and upbringing, depriving itself of the future...

The exhibition has ended. Here is what A. Gurauskas, director of the Moskva center for the scientific-production complex for organizing the exhibition, said about it: "This function was the largest one of the year. It was complicated to prepare. We have display footage and lease fees, after all, but the approaches to the participants were tailored. Not everything turned out as planned. The advertising section, for example, did not work out. It was a good idea—give any organization an opportunity to advertise its products for a fee. But there were few submissions; the announcement in the press was late. More than 60 participants and about 500 exhibitors, however, is still a pretty good result. The International Philatelic Federation supported the exposition. Some 57 of the 160 collections were foreign..."

There were quite a few other interesting expositions, but unfortunately you cannot talk about all of them in a brief report. We wish success to those who did not "drop their oars."

Development History of Spacecraft from Ballistic Missiles Recounted

92UM0108G Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 34-35

[Article by Doctor of Technical Sciences Yu. Mozzhorin and Candidate of Technical Sciences A. Yeremenko under the rubric "From the History of Space Science": "From the First Ballistics to..."; conclusion—for beginning see No. 7]

[Text] The R-2 missile had a separating warhead and integral fuel tank. Lateral radio correction was incorporated into the control system. The first achievements of the Soviet missile builders are now diminished in every way in the West. The concrete facts, however, refute these intentions by the authors of various types of memoirs. It is sufficient to present just one example. German specialists headed by W. von Braun, having become American by that time, were taking the path of modernizing the German V-2, and only by 1953 had they created the Redstone rocket with a range of 320 km [kilometers]. Improvements in it ended in 1955 when a range of 640 km was attained, while the R-5 rocket with an operating radius of more than 1,000 km, executed entirely according to a fundamentally new design, had already been created by that time at the NII-88 [Scientific-Research Institute 88].

The new SKB-586 [Special Design Bureau 586] based on the Dnepropetrovsk Motor Works was organized in 1952, and the series production of the R-1, R-2 and then the R-5 missiles was transferred there. It was soon entrusted with the th development of new missiles using high-boiling fuel components. The SKB was headed by the talented designer M. Yangel starting in 1954. This collective created a whole family of strategic medium-range and intercontinental missiles over a short time,

which meticulously served and continue to serve as one of the substantial elements of the strategic parity of our Motherland.

The first operational-tactical missile, the R-11 using storable fuel, was created at the NII-88 in 1953 and began to undergo flight testing. It had the same characteristics as the R-1, but the mass was several times less, and it had fundamental advantages in operation. A shipborne combat missile was being developed on the basis of it at the same time, and test launches from submarines began. Further work on naval missiles was transferred to a newly created OKB [Special Design Bureau] headed by V. Makeyev.

The chief mission of the SKB headed by S. Korolev at that time became the planning of the powerful R-7 two-stage intercontinental ballistic missile, which was to become the world's first space launch vehicle. The work on it started in 1954, and as early as 21 Aug 57 an R-7 launched from the space center at Baykonur had attained the nominal flight range.

After the launch of the first artificial Earth satellite, S. Korolev was switched over to a considerable extent to space topics, giving priority to the assimilation of space by man. Automatic apparatus also occupied a very large amount of the work of his OKB as well, since it was to lay the path into space and make the first reconnaissance of the conditions in interplanetary space. The community of missile and space collectives created the first automatic interplanetary stations for researching the moon, Venus and Mars, the first Elektron research satellite system, the first Zenit satellite for observing the Earth from space and the first Molniya communications satellite on the heels of the first artificial Earth satellites. Parallel work was proceeding on the creation of the Vostok and Voskhod manned spacecraft, and then the more advanced Soyuz. The R-7 had to be seriously refined to launch these satellites, adding a third and then a fourth stage to the design. These launch vehicles are in service today as well.

It was more and more difficult to develop various thematic areas within the framework of the OKB-1, which had spun off from the NII-88 in 1956. S. Korolev thus spun these areas off into independent KBs [design bureaus], turning over his deputies and best cadres to them to continue the work they had started. KB imeni S.A. Lavochkin Chief Designer G. Babakin, a protégé of Korolev, was thus given the development of automatic space stations for studying the moon, Venus and Mars. A new KB headed by M. Reshetnev, who had left the OKB-1, was entrusted with the development of communications satellites. A newly organized KB under the leadership of Chief Designer D. Kozlov was engaged in the improvement of launch vehicles based on the R-7 missile, and he later formed a new area for the development of spacecraft for the remote sounding of the Earth and the performance of biological, technological and other experiments.

Virtually all of the pilot enterprises working in the realm of space technology had thus grown up based on the NII-88 and the OKB-1 that came from it. The only exception was the OKB-52 headed by General Designer V. Chelomey, with the Aviation Plant imeni M.V. Khrunichev that had been given to him, which went over to work on space topics while still part of the aviation-industry system.

The administrative coordination of all work on missile building was accomplished by a specially created body of the USSR Council of Ministers, the Committee on Missile Technology, later called Special Commission No. 2, headed by CPSU Central Committee Politburo member G. Malenkov. His first deputy was Minister of Armaments D. Ustinov, who answered for the development of missile and space technology overall. The 7th Chief Directorate, headed at the time by S. Vetoshkin, was created for the same purpose within the Ministry of Armaments itself. This chief directorate was subsequently transferred, to the extent of changes in the structure of the supervisory bodies of Soviet industry, from the Ministry of Armaments to the USSR Ministry of the Defense Industry, and then to the USSR State Committee of the Council of Ministers for Defense Technology (GKOT), finally becoming in practice the foundation of the USSR Ministry of General Machine Building, headed for a prolonged period by its first minister S. Afanasyev, who made an exceptional contribution to the development of the missile and space industry.

The chief customer, the USSR Ministry of the Armed Forces, played an important role. A special directorate was organized in it that was part of the Chief Artillery Directorate (GAU), which then became the Directorate of the Deputy Commanding General of Artillery (UZKA) and later the Chief Directorate of Jet Armaments (GURVO). These directorates were headed by R. Sokolov, A. Semenov, A. Vasilyev and N. Smirnitskiy, whose direct superiors were Marshals of Artillery N. Yakovlev and, later, M. Nedelin, who became the first commander-in-chief of a new branch of the armed forces of the USSR—the Strategic Missile Troops—that was formed in 1959.

A missile and space industry was thus created in a short period of time that provided for the strategic parity of our country and brought glory to our Motherland as the leading space power.

Theoretical Physio-Chemical Propulsion System Proposed

92UM0108H Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) p 35

[Article by Doctor of Technical Sciences A. Kulikov under the rubric "Science—Space Science": "Into Space by Steamplane"]

[Text] The idea of using a new power source in missile and space technology arose unexpectedly in the process of studying the properties of carbocorundum refractory materials that are employed in thermal units in the glass industry in their interaction with melts of silicates of alkali metals. The results of that work were published in 1984 in the journal IZVESTIYA AN SSSR. NEORGANICHESKIYE MATERIALY (Vol. 20, No. 1).

It turned out that the reactions that take place are of a chain nature and are accompanied by a considerable release of heat. Approximately 8.5×10^6 kcal are released, for example, in the splitting of one kilogram of Na_2O $3SiO_2$, which is a thousand times more than in the combustion of one kilogram of kerosene.

High-modulus silicates should serve as the working medium in such a physio-chemical reactor, with anoxic silicon compounds to initiate the chain reaction. Silicates of the $M_2O \xi SiO_2$ type must be employed, where M is an alkali metal (Na, K), and $\xi = 3; 4$ respectively. The reaction is launched by the SiR type compound, where R is hydrogen or nitrogen. The aforementioned Na_2O $3SiO_2$, known as impure sodium disilicate, is produced by domestic industry in the quantity of about 1.5 million tons a year at a price of less than 100 rubles per ton. It is formed from soda and sand. About 2,500 times less energy is expended therein than is later released in the chain-reaction process.

How does the decay of the matter occur in the proposed physio-chemical reactor? It is first necessary to total up the energy that is necessary for melting down a portion of the silicate. The expenditure of heat is not needed after this, since a chemical reaction with the release of heat starts in contact with the anoxic-silicon substance, leading to the meltdown of an ever larger quantity of the silicate. The process will continue until the mass of the reagent in the liquid phase becomes equal to the critical mass. The chain reaction starts at that moment, and is accompanied by an avalanche release of energy. If this process is not controlled, an explosion can occur after the meltdown of all of the mass (which has occurred at metallurgical enterprises).

How to escape this situation? It was already mentioned above that an anoxic-silicon compound—for instance silicon carbide, a solid, refractory substance—is required to initiate and sustain the reaction. It is namely that, in the form of rods inserted into the area of the melted silicate, that determines the speed of the reaction. It increases with the movement of the rods into the reactor, with the release of heat increasing as well, while it decreases with retraction. These rods will thereby maintain a balance of the heat released and consumed, which averts an explosion and provides for the necessary capacity of the power installation.

So this is how the configuration of a new and efficient power source is represented. It is especially suited for transport, since it is very important therein that the share of payload in the overall mass be as large as possible. The lighter the power installation, therefore (along with the working medium), the better. Even the steam locomotive could gain a second life—no harmful emissions, and energy released in the decay of the silicate that is almost a thousand times more than coal. Such a locomotive need be fueled only with water, with the core of the reactor changed now and then. The steam could drive a piston, which could turn a turbine.

A steam locomotive has to carry water with it, however, while a steamship, aircraft or dirigible uses the surrounding environment—water or air—as a working medium. They need only a source of energy. A new reactor employed in those means of transport will lead to revolutionary transformations. They will include, aside from all the rest, ecologically clean means of locomotion. If this proposed power plant is suitable for a steamship, however, why not install it in a rocket?

Imagine that same water as the working medium. It is pumped from one of the rocket's tanks through channels in a heating reactor and is discharged from a nozzle at high pressure and temperature, creating thrust. A launch vehicle with such a power plant could prove to be lighter than one with a liquid-fueled engine. How so? Through economies in the design mass. A tank almost 15 times smaller than for hydrogen, and 1.5 times less than for kerosene, is required for water. It is still too early to talk about the magnitude of the unit thrust, but the temperature in the combustion chamber depends on the type of silicate. We will say that it could be about one and a half thousand degrees for impure sodium disilicate and more for other types; they are currently produced only in small quantities, however—there is no need for them.

The relative efficiency of the proposed system could be higher as a consequence of the effects of the Gibbs law of the shift of energy. It follows from that in particular that oxygen and hydrogen could react with each other at just roughly 60 percent.

What about the cost? It is clear to all that the cost of water is incomparably lower than any of the components of rocket fuel, especially the liquefied gases.

Many operational problems are also eliminated. The working medium is safe against fire and explosion, and is not harmful. The advantages are even more obvious if we compare it to toxic substances. The harmful effects on the environment during the flight are also undoubtedly much less. Even launch vehicles with engines using oxygen and kerosene cannot equal the proposed rocket, since they form carbon dioxide and carbon monoxide gases and a mass of impurities in operation.

The fact that the regeneration of the matter in the core is simple to achieve when using returnable stages is also of no small importance. High-modulus silicate is obtained anew as a result. The waste-free technology reduces the cost of the power installation significantly. These and many other advantages could provide a use for the new energy source in space engineering.

The joint efforts of scientists and practitioners from various realms of science and technology are obviously needed to create a workable and reliable power installation for the future. Interested organizations already exist. Practical steps are required.

Insurance Company Offers Coverage to Servicemen in Aviation

92UM0108I Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 91 (signed to press 19 Aug 91) pp 38-39

[Interview with Russian Transport Insurance Company Vice-President Oleg Leonidovich Alekseyev by Lieutenant-Colonel A. Zhilin under the rubric "Topical Interview": "A Fee for... Risk"]

[Text] *A payment for risk is guaranteed to military fliers by the Russian Transport Insurance Company, an interview with the vice-president of which, Oleg Leonidovich Alekseyev, we offer to the readers.*

[A. Zhilin] Oleg Leonidovich, tell us briefly what your company is involved in.

[O.L. Alekseyev] The essence of the activity of the Russian Transport Insurance Company (RSTK) is insurance for the employees of transport enterprises whose work entails increased risk, as well as providing new forms of insurance protection for the economic interests of the enterprises, organizations and institution themselves. I especially want to emphasize herein that military fliers are also in the sphere of our activity—pilots, navigators, engineers, technicians etc.—insofar as their service is accompanied by extreme situations. The state, when setting up the mutual relations with the protectors of the air, unfortunately did not take into account the hazards of their labor either in their wages or in their social guarantees. The RSTK has thus decided to take on some of these functions itself.

[A. Zhilin] All servicemen are currently obligated to insure themselves, so to speak, in centralized fashion, through the USSR Ministry of Defense. According to the information available to me, however, it is difficult to get the full amount of the "benefit," since all sorts of officials and commissions try to trim the amount intended for payment. Do these bureaucratic "charms" also affect the fliers who have decided to take advantage of the services of your company as well?

[O.L. Alekseyev] Not at all. Our company has simplified the procedure for the payment of the appropriate amount to the utmost. The person or organization is guaranteed to receive the money due within three days.

[A. Zhilin] Good. But... There is a specific nuance to military aviation. If there is a precursor to a flight accident, if the pilot ejects or, God forbid, is killed, all of the blame for what happened, by virtue of a number of reasons, is placed, as a rule, on the pilot. Will the RSTK dig down to the truth of whether the insured pilot is really to blame for what happened or, on the basis of the conclusions of the military commission, refuse to pay the "benefit"?

[O.L. Alekseyev] No, the RSTK will not dig for the truth independently. In exactly the same way that there is no need to study the conclusions of the commission. Those materials have no effect whatsoever on the company's fulfillment of its obligations. The flier or his family will get what is stipulated by the terms of the contract. I repeat—within three days.

[A. Zhilin] That is, even before the completion of work by the commission investigating the flight accident or the preconditions of it?

[O.L. Alekseyev] Absolutely right. Our company is entirely independent of the state and military administration.

[A. Zhilin] I want our fliers to understand an axiom. The Russian Transport Insurance Company, as opposed to the corresponding state and army power structures, feels that the pilot, with his most difficult labor that entails constant risk, and his family should be guaranteed material compensation. You will accuse me of harshness, but it is a national disgrace that when a tragedy occurs in a flight regiment, the pilots pass the hat around so as to collect at least something for the family of their comrade.

The guarantees that I have been talking about can and must be provided with the aid of flexible insurance. A fixed insurance fund should be put together, from the funds of which the payments will be made to the military fliers. We are actively engaged in the formation of such a fund.

[A. Zhilin] Oleg Leonidovich, does a flier who is already insured by the Ministry of Defense have the right to collect on two policies, one from the Ministry of Defense and one from the RSTK, or is only one of them paid?

[O.L. Alekseyev] Our company pays regardless of the amounts paid under the compensation for damages under state or social insurance and security. That is, the RSTK pays on top of those amounts. The fact that our payments are not subject to taxation is also important.

[A. Zhilin] How is the insurance fund put together?

[O.L. Alekseyev] Various approaches are used for this. The fliers should understand one fine point quite well—the more officers that are ensured, the less the rates that they have to pay will be. The terms moreover depend on the versions of the insurance. A pilot, for example, can be insured against unforeseen events both on the ground and in the air; he can also be covered just for the air, and the like. The company has developed some 40 types and terms of insurance overall. The accrual insurance is very advantageous. It is accomplished as follows. A flier, by way of example, is insured for ten thousand rubles. He pays this premium to the company in advance for the

whole term of the insurance, say for three years. At the end of the term he is paid not ten, but twelve thousand rubles. The investment increases by twenty percent, in other words. No other company is paying this kind of interest. Not to mention the state bank...

[A. Zhilin] A person gains double, in other words—he is insured and he increases his investment?

[O.L. Alekseyev] You are correct. If a covered condition occurs, he receives the amount of the "benefit" due to him plus twenty percent (of the invested amount) upon the completion of the contract.

[A. Zhilin] Oleg Leonidovich, how can mutual relations be structured with your company—are the pilots, say, insured in centralized fashion by the leadership of the Air Forces (if the funds can be found), or can they do this individually?

[O.L. Alekseyev] We have very flexible forms of insurance. The pilots can be insured both in a centralized fashion or individually. And even, as they say, in mixed form. That is, for instance, eighteen percent of the amount is paid to the Air Forces leadership, and twenty to the pilots. Any and all ratios are possible. There are no bureaucratic hurdles here.

[A. Zhilin] Let's elaborate the procedure in more concrete terms. If, for example, a pilot is insured for a hundred thousand rubles, how much does he have to pay the company?

[O.L. Alekseyev] With a benefit amount of a hundred thousand rubles, if we calculate that the premium rate is on the order of ten percent, he must accordingly pay in ten thousand rubles. If the amount of the insurance is less, say fifty thousand, then the premium decreases in accordance with the rate scale, and will be less than five thousand rubles.

[A. Zhilin] Are there any concrete examples where the RSTK has paid the "benefit" to specialists who ran into various difficult situations in the course of their activities?

[O.L. Alekseyev] There are quite a few such examples. The most characteristic of them is the incident with cosmonauts Musa Manarov and Viktor Afanasyev. They were insured by our company before their launch into space. They had certain difficulties during their work in orbit, as is well known, when certain complications occurred that entailed moral losses. Gosstrakh [State Insurance], I would note, does not react in this case at all. The Russian Transport Insurance Company paid each of the cosmonauts five thousand rubles apiece. This fact is noteworthy for pilots in that, taking advantage of the services of the RSTK, they can receive a "benefit" not only in the event of an accident, but also the precursors to a flight accident that threaten the health or life of the pilot.

[A. Zhilin] Oleg Leonidovich, the unpredictable policies of the country's leadership, paradoxical as it may sound, have led to the fact that a real threat of being unemployed hangs over the military person. I have this question regarding that: if the next wave of cutbacks rolls over the armed forces, can the fliers discharged from the service count on receiving compensation from the RSTK?

[O.L. Alekseyev] That is a very important and topical thing for every serviceman. The military fliers can be sure that the company, having taken on insurance obligations, will fulfill them unconditionally. They will be paid substantial compensation for getting set up in civilian life if they are discharged from the armed forces due to personnel cutbacks. We are already completing the development of insurance for a condition, new to our country, that around the world is called unemployment. It will also have a long-term basis, since unemployment is an unpredictable phenomenon.

[A. Zhilin] What amount can a flier who is discharged into the reserves due to cutbacks receive?

[O.L. Alekseyev] The minimum amount should be five or six thousand rubles. Other variations are also possible under which it would be more. These fine points should be stipulated in the contract.

[A. Zhilin] The headquarters of the Russian Transport Insurance Company is located in Moscow; how can the fliers get into contact with it?

[O.L. Alekseyev] The RSTK has offices in Leningrad, Vladimir, Irkutsk, Ryazan, Astrakhan, Murmansk, Kurgan, Sochi, Kostroma, Bryansk, Ivanovo, Voronezh, Orel, Pskov, Vologda, Krasnodar, Yaroslavl, Yakutsk and Yuzho-Sakhalinsk. We can offer another variation as well—a flier can write an application and send it to the editors of AVIATSIYA I KOSMONAVTIKA, and you will pass it along to us in operative fashion. We will complete all of the remaining formalities very quickly.

[A. Zhilin] A final question. Can servicemen who are completing their service in other republics of the country take advantage of the services of the RSTK?

[O.L. Alekseyev] Undoubtedly. For that, as we have already agreed, they will have to send editors of the journal a written application, indicating their full return address. No geographical boundaries exists for insurance by our company.

From the editors: *All fliers who would like to make use of the services of the Russian Transport Insurance Company can write to the journal editors at the following address: 125083, Moscow, A-83, AVIATSIYA I KOSMONAVTIKA, RSTK.*

Development of Air-to-Air Combat Tactics Traced

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[Article by Candidate of Military Sciences V. Dubrov under the rubric "In the Air Forces of Foreign Armies": "In Search of New Tactics"; conclusion—for beginning see Nos. 3-7]

[Text] *(From materials in the foreign press)*

6. Multiple-Aircraft Air-to-Air Combat

Technical progress (the fitting of aviation systems with the latest in electronic equipment, increased flight speeds, growth in the destructive capabilities of weaponry) has predetermined the tactics of aerial battle in local wars. The chief aim that was being prosecuted by the attacking side was to prevent disruption of the fulfillment of combat missions of strike aviation by enemy interceptors.

The aerial battles in Korea between the first subsonic jet fighters remained multiple-aircraft and maneuvering ones, even though the spatial framework of the confrontation had expanded and the pace of it had increased. The chief impediment to fundamental changes were the outmoded armaments. The cannons and machineguns that remained on board the aircraft did not allow an extension of the realm of possible attacks. The necessity of getting the fighters into the "mobile" rear quadrant of the enemy kept the battle maneuverable, with compensation for the inadequate power of the weaponry through the "number of barrels"—multiple aircraft.

The equipping of the Air Forces with supersonic missile-carrying aircraft opened up the way for the tactics of interception. High-speed bombers—the targets for "destruction" by the fighters—strove to break through to assigned ground targets on a straight line, one by one, the way the tactics were rehearsed under peacetime conditions. Multiple-aircraft maneuvering battles became a rarity, and interceptors also made solo flights according to commands from the ground.

American pilots, trained in instrument interception in bad weather conditions and the use of missiles against non-maneuvering targets, got into a difficult situation right from the very start of the war in Vietnam—they were intercepting their own planes. Phantom fighter units that were covering their own bombers making massive strikes against targets in North Vietnam had to wage defensive battles as part of pairs and flights and employ methods of group protection. The former interceptors were not successful in this, as confirmed by their striking losses in the face of an overwhelming numerical superiority in the air.

The causes of failures in the multiple-aircraft battles can be discerned in the following.

First, the great distance of the strike targets from the base airfields, which did not permit the organization of radar monitoring of the flight of the aircraft over the whole distance of the routing and the provision of information to the crews on the aerial situation in the combat zone. The likelihood of effective surprise attacks on the part of North Vietnamese fighters increased considerably under those conditions.

Second, the limited opportunities for waging battle by the escort. The aircraft in the strike group, loaded with bombs, kept to low flight speeds. The fighters, in order to avoid losing visual contact with them, were to keep their place in the formation by equalizing their speed. Devoid of the necessary reserves of energy, they were not ready to begin fighting attacking MiGs on an equal basis.

Third, the costs of retraining in the course of the war. The American pilots were not able to eliminate all of the gaps in their tactical flight training in a short period of time. The defeat in multiple-aircraft battles was a consequence of the poor coordination of the aircrews and breaks in the battle formation. The preventive measure that was instituted, which the command felt was forced, was a large penalty for the loss of the lead.

And, **fourth,** the shortage of "guides"—lead groups—and disruptions in combat command and control. The lessons learned forced them to include the following lines in the manual for the combat application of tactical aviation: "The ability to lead in the air is a talent not given to everyone. It should be revealed, encouraged and developed. A pilot who has demonstrated the ability to command crews in battle should be promoted immediately."

The new requirements of tactics forced a search for more effective methods of "aerial incursion." The traditional escorting of bombers was supplemented with a screen, which was extracted from the depths of experience of World War II. This method was based on the organization of several combat air patrol zones located 15-20 km [kilometers] from the strike targets, that is, roughly at the formation break-up line. Three or four such zones were designated during mass raids by American aircraft on targets in the DRV [Democratic Republic of Vietnam], which were occupied by two flights each of F-4E Phantoms that were usually stacked by altitude in two tiers. The overall quantity of fighters in the screen thus reached 24-32.

The screening groups advanced at an altitude of 4,000-8,000 meters in the direction of the base airfields of the North Vietnamese interceptors 8-10 minutes before the bombers reached the target. The maneuver of flights in the patrol zone was arranged to provide the crews with favorable opportunities for detecting hostile aircraft in the air.

The screen had a number of advantages compared to direct escort, first and foremost the relative independence of action of the fighters and the free choice of maneuver. They were not part of the bombers' battle

formation, even though they had been assigned to cover it. It was not necessary to maintain visual or radio contact with the strike groups. The opportunity arose of changing altitude, which improved the conditions for entry into battle and provided hope of reducing the effectiveness of attacks by North Vietnamese pilots. The threat of defeat by ground fire partly eliminated fighter access into areas within reach of small-caliber anti-aircraft artillery in altitude or over the line of the lethal limits of guided missiles in range.

The dual ring of bomber protection using an escort and a screen inevitably led to violations of the principle of the economical expenditure of forces. Whereas the ratio of strike and protective (support) aircraft was equal to 3:2 in World War II (three flights of bombers covered by two flights of fighters), local wars made that ratio at least equal.

The Israeli Air Forces made an attempt to get rid of escorts and limit themselves just to screens during the October War of 1973 under the pressure of the unproductive consumption of combat resources for support. The screen groups were located over their own territory during combat operations by ground-attack aircraft in close-in tactical depth, and they advanced only on order from a command and control post that had detected the appearance of Arab fighters.

Further improvements were made in the "tactics of incursion" in the war with Lebanon in 1982, where F-15 and F-16 fighters, as well as the E-2C Hawkeye (land-based) airborne command posts [VKP] and Boeing 707 EW aircraft (passenger aircraft refitted by the Israelis), were employed for the first time.

Before the Phantom strike groups reached Lebanese territory, the entire independent battle formation was a multi-tiered structure located beyond the limits of the area of combat operations. The light F-16 fighters were in the lower tier, with the medium altitudes occupied by the Hawkeye and F-15 aircraft and the higher ones (and further away over the sea) by the Boeing 707 jamming aircraft. The Hawkeye airborne command posts usually had close-support cover—a pair of F-15s.

The fighters were on combat patrol before their entry into battle, without crossing the lethal line of enemy air defenses. The Hawkeye aircraft was removed even further to the rear, corresponding to the official views on the location of command and control aircraft during the course of an offensive operation.

Each element of the combat formation was performing its own mission, but all of their actions were coordinated by and subordinate to the overall battle plan. The most mobile portion of the formation was the groups (flights) of F-16 aircraft, which were oriented toward waging close-quarters maneuvering aerial battle. The groups of F-15 fighters, equipped with medium-range Sparrow missiles and attacking, as a rule, from the rear quadrant, were more "stable." The F-16 flight went first at the direction of the Hawkeye aircraft, and when converging broke up into pairs and performed group flanking maneuvers—the "sandwich" tactical device. The break-off, performed at low altitude, was accompanied by jamming cover from the EW aircraft. The F-15 pairs with the "heavy" weapons entered a group confrontation according to the situation—most often after the breakup of the combat formation of Syrian fighters and the presence of "solos" in the air that had broken off from the formation. The withdrawal of the aircraft from battle was accomplished by the VKP.

The material base of tactics for multiple-aircraft air-to-air combat thus underwent substantial changes in the course of improvement. An external control organ—the VKP—and a specialized EW aircraft entered into it aside from the two types of fighters; the former supervised the fighters, while the latter provided jamming support for their concealed entry into battle. The extension of the VKP radar field into the area where multiple-aircraft combat was being waged provided for the issue of command and other information to commanders and group leaders, easing the process of making decisions for them and providing a reserve of time for taking up an advantageous position before entry into battle with the enemy.

The functioning of this command and control system was facilitated by the geographical location of Lebanon, whose territory borders the Mediterranean Sea. The fighter screen was over neutral waters in its start positions, which guaranteed its safety. The two elements of the immobile echelon—the VKP and EW aircraft—were also located with them. Specialists emphasize that it is not possible to repeat this variation in the annual tactical exercises of the combined NATO Air Forces in Europe. The information field of the VKP embraces just a portion of the routing in the flight of bombers on the full combat radius. The escort, as a rule, experiences an acute shortage of information about the aerial situation at the engagement line with enemy interceptors. The problems thus remain, as confirmed by calculations and means of objective monitoring recording the unsatisfactory survivability of escort groups.

The opportunities for modeling tactical systems have made it possible to research the flight conditions of mixed incursion groups at operational depth. A variation for escorting a flight of bombers with a flight of fighters encountering resistance from four enemy interceptors was evaluated in particular. The destructive capabilities of the aircraft were considered to be equal. The calculations showed that the escort loses an average of up to 40 percent of its forces, the bombers up to 30 percent and the enemy interceptors up to 20 by the end of the third minute of battle. The rear quadrant is especially dangerous for an escort attached to a strike group. They have to turn around, leaving the aircraft they are covering, in order to repel attacks from that direction. The main factor facilitating the success of the interceptors proved to be the advantage in information, providing warning of active operations and allowing them to take up advantageous tactical positions before entry into battle.

Multiple-aircraft battle "in escort" thus continues to remain difficult as well as dangerous for support aircraft. The appearance of medium-range missiles among the interceptors has forced the escort to be moved further away from the covered bombers to increase the reliability of their protection. The breakup of the conventional battle formation and removal of protective forces outside the limits of visual contact make the organization of interaction much more difficult. Hopes of steady radar contact between the escort and the bombers, especially under conditions of intensive jamming, are considered to be illusory. Escort units in the latest air exercises in Europe were typically given permission to cease functioning as escorts after entry into battle. This was, however, a return to the Vietnamese variation of the non-economical expenditure of forces.

On the agenda today, however, is a search for the solution to many problems connected with supporting the combat operations of strike air groups. The **first** of these problems is how to refrain from organizing a "unified formation" with bombers (the incursion forces) that ties up the maneuvering and diminishes the combat capabilities of the fighters, and to make the transition to operational interaction in time and points of engagement. The **second** is how to "move" the information field along with the mixed battle formation, providing for the timely detection of an attacking enemy at ranges that guarantee the execution of answering defensive maneuvers and the use of weapons "to repel."

The winning of full air superiority always was and remains the main thing, as was confirmed yet again by the combat operations of the multinational forces against Iraq.

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